UNITED STATES
DEPARTMENT OF TRANSPORTATION

ITS ePrimer
Module 2: Systems Engineering

September 2013

Intelligent Transportation Systems Joint Program Office
Research and Innovative Technology Administration, USDOT

This is the first, title slide in all modules.

The following slides are in this order:
- Instructor
- Learning Objectives
- Content-related slide(s)
- Summary (what we have learned)
- References
- Questions?

This module is sponsored by the U.S. Department of Transportation's ITS Professional Capacity Building (PCB) Program. The ITS PCB Program is part of the Research and Innovative Technology Administration's ITS Joint Program Office.

Thank you for participating and we hope you find this module helpful.

Instructor

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Learning Objectives

1. Provide an introduction to the systems engineering process (SEP) and how to apply it to the development of ITS projects

2. Provide an overview of intelligent transportation systems (ITS) architectures

3. Review the role of ITS standards in the development process

4. Discuss the Architecture and Standards Rule and the role of Systems Engineering and ITS Architecture in addressing the requirements of the rule

5. Identify how SEP supports transportation planning

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Introduction

What is Systems Engineering?

According to the International Council on Systems Engineering (INCOSE) Handbook (2007):

"Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems."

Key Message: Definition of Systems Engineering (SE)

Source: *INCOSE Systems Engineering Handbook*, Version 3.1, 2007.

What Is Meant by Interdisciplinary Approach?

- The application of <u>basic engineering discipline</u>, <u>management discipline,</u> and expertise in whatever <u>applications domain</u> the system lies.
- For ITS, the basic engineering discipline is Transportation Engineering.
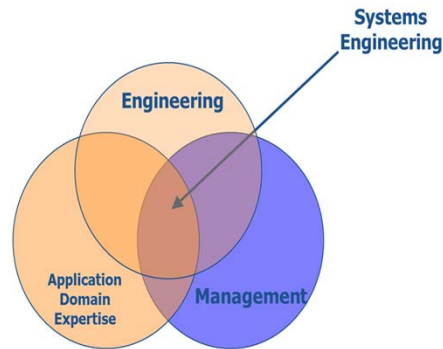
Source:
"RITA: National ITS Architecture SE Process Improvement Presentation"

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Key Message: Discusses what is meant by interdisciplinary approach with regard to SE. To successfully develop a system requires the application of basic engineering discipline, management discipline, and expertise in whatever application domain the system lies. In the case of ITS systems, that application domain is transportation engineering. The intersection of these disciplines is the realm of Systems Engineering.

Source: RITA: National ITS Architecture SE Process Improvement Presentation

Key Concepts of Using the SEP

The systems engineering process (SEP) seeks to:
- Consider the entire life cycle of a system
- Focus on stakeholder involvement
- Understand the problem to be addressed
- Address project risks as early as possible
- Clearly document the process and the output of each step
- SEP is scalable based on size, complexity, and risk of project

Key Message: Lists several key concepts of SEP.

• Consider the entire life cycle of a system. SEP does not just concern itself with the timeline of a project's start to completion; SEP considers planning activities that occur before the project starts. SEP covers steps following initial deployment including operations and maintenance and system retirement or replacement.

• Focus on stakeholder involvement. SEP involves the stakeholder in all steps in the process, from identifying the needs through system validation. Stakeholder involvement is a key to the successful application of SEP.

• Understand the problem to be addressed. View the problem from the stakeholders' point of view by defining needs from the user's perspective.

• Address project risks as early as possible. The earlier a risk is identified and resolved, the less cost and/or schedule impact there will be on the project.

• Clearly document the process and the output of each step. SEP should be tailored to each project—it is not one-size-fits-all. Regarding outputs, stakeholders must review the outputs of each step in the process and make informed decisions about proceeding to the next step.

• SEP is scalable based on the size, complexity, and risk of a project. SEP is definitely not a one-size-fits-all process. It can and should be tailored to fit the needs of the project.
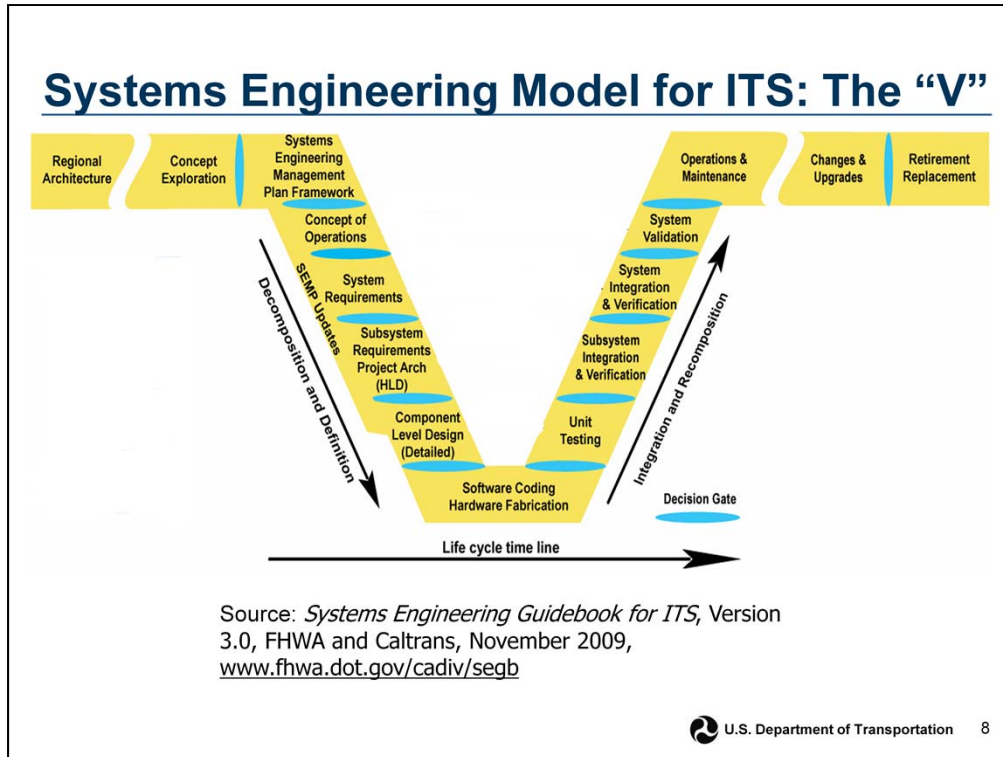
Benefits and Costs of SEP

- Benefits
  - Improve the quality of products created by the project
  - Reduce the risk of schedule and cost overruns
  - Increase the likelihood that user needs will be met
  - Improve stakeholder participation
  - Provide better documentation
  - Reduce operational costs
- Costs
  - SEP causes some reapportionment of cost with additional effort needed early in process and during verification

Key Message: Summarizes benefits of SE and the cost of using the SEP.

Benefits: Systems engineering can improve the quality of the products created by an ITS project, reduce the risk of schedule and cost overruns, and increase the likelihood that the implementation will meet the user's needs. Other benefits include improved stakeholder participation and better documentation of not only the end products, but of the development process itself. Anyone who has tried to pick up a project midstream after a key person unexpectedly leaves will understand the benefit of good documentation during the development effort. In addition, the benefits of using the SEP can continue throughout the life cycle of the system developed through reduced operational costs as a result of implementing the product correctly the first time, thereby reducing the need for later modifications.

Cost: The SEP has several outputs prior to the design phase that require expenditure of resources to complete, but doing this can provide the benefits shown. In general, the use of SEP will result in more effort expended at the early stage of the development process—those steps leading up to detailed design. Additional costs may also be incurred during the systematic verification.

Systems Engineering Model for ITS: The "V"

Source: *Systems Engineering Guidebook for ITS*, Version 3.0, FHWA and Caltrans, November 2009, www.fhwa.dot.gov/cadiv/segb

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Key Message: Shows the "V" Model defined and used by USDOT

Covers complete life cycle of a system, from project planning through to retirement or replacement
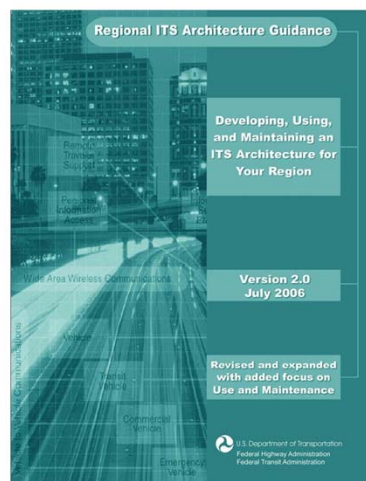
The next set of slides covers the steps of the "V" one slide per step.

Source: Systems Engineering Guidebook for ITS, Version 3.0, FHWA and Caltrans, November 2009, www.fhwa.dot.gov/cadiv/segb/

Key Message: Defines a Regional ITS Architecture

Source: Copy of cover of USDOT *Regional ITS Architecture Guidance* document

Concept Exploration

- Perform initial feasibility, benefits analysis, or needs assessment
- Evaluate alternative concepts
  - Prior to initial investments
- Provide justification for a project to move forward into development
- Make the business case
- Decision gate: Obtain management approval to proceed into the programming of funds phase

Key Message: Describes the Concept Exploration step, which occurs before project is funded.

The Concept Exploration step in the process is used to perform any initial feasibility, benefits analysis, or needs assessment required to facilitate the planning of the system. This results in a business case and specific cost/benefit analyses for alternative project concepts. The output of this step can be a definition of the problem space, key technical metrics, and refinements to the needs, goals, objectives, and vision. This step provides the justification for the project to move forward into development. This activity may result in combining or dividing candidate projects based on the best cost/benefit analysis. This step has the first of many "decision gates" that show as the light blue ovals between steps in the "V" diagram. These decision gates represent key points in the process where a specific decision is made, based on documented outputs or possibly technical reviews, to advance to the next step in the process.

SE Management Planning

- Development of SE Management Plan (SEMP) for managing the technical effort on a project
  - Technical planning and control of the project
  - Systems engineering processes to be used for the project.
- 2-stage process
  - 1st – SEMP Framework
    - Developed at project initiation
  - 2nd – SEMP Plan Development
    - Developed as project proceeds

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**Key Message:** Defines a SEMP and describes the two-stage process.

Framework covers the two sub-bullets under the first bullet. Also defines all the other plans that will be created as part of the 2nd stage.

The SEMP identifies all the required documents and plans that will need to be developed throughout the project. The initial version of the SEMP (sometimes referred to as the SEMP Framework) is developed at the beginning of the project and is usually not a large or complex document as it is basically an outline of what is to come. While the SEMP is a fairly new concept in ITS project development, it is an extremely important tool for managing the technical side of the project. *The SEMP is intended to guide the agency or owner of the project in the management of the project. It is not meant to be a document written by the contractor on a project for their own internal management, rather it is the primary tool for the project owner to monitor contractor work and progress.*

Source: Portion of "V" diagram

Concept of Operations

- Purpose of the Concept of Operations (ConOps) is to clearly convey a high-level view of the system to be developed that each stakeholder can understand
- Answers who, what, where, when, why, and how about the system from the viewpoint of each stakeholder
- User needs are identified at this stage
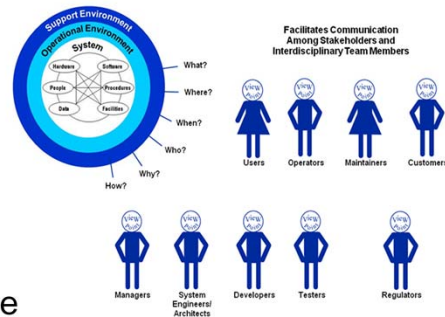
Used with permission from the American Institute of Aeronautics and Astronautics

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Key Message: ConOps is first key output of the SE process. Defines user needs. Document is written in language stakeholders can understand.

The ConOps stage of the systems engineering process is used to ensure that the system developers document a thorough understanding of the users' needs.

This step embodies several of the key concepts of SEP—engaging the stakeholders (whose input is key to the development of the ConOps), focusing on the problem and user needs, and beginning with the end in mind (i.e., defining key system outputs as well as key operations and maintenance considerations).

Note that for this and all the other SEP documentation—not always created from scratch for each project—you may reuse or update documentation the agency has created for similar types of projects.
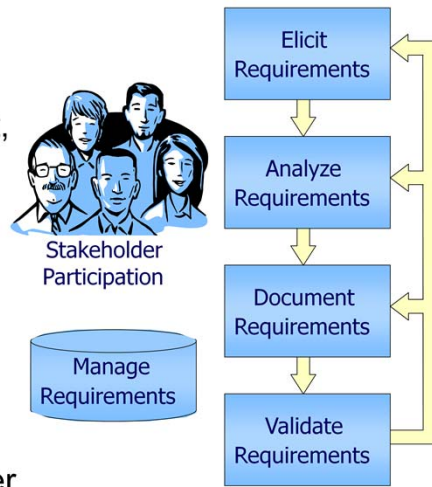
Source: Diagram used with permission from the American Institute of Aeronautics and Astronautics from *Guide to the Preparation of Operational Concept Documents* (ANSI/AIAA G-043A-2012e). This report is based on a cooperative effort between AIAA's Systems Engineering Committee on Standards and the INCOSE Requirements Working Group, providing a systems-level viewpoint and inclusion of

international knowledge, information, and experiences that have been recognized since the Guide's original publication.

This edition has been broadened to encompass the development of all system types, including software-intensive systems, and to reflect technological advances of the last two decades. It describes which types of information are most relevant, their purpose, and who should participate in the operational concept development effort. It also provides advice regarding effective procedures for generation of the information and how to document it.

System Requirements

- According to EIA 632, a System Requirement is "something that governs what, how well, and under what conditions a project will achieve a given purpose."
- Types of Requirements
  - Functional: define "what"
  - Performance: define "how well"
  - Non-functional: define "under what conditions"

Stakeholder Participation

Manage Requirements

Elicit Requirements → Analyze Requirements → Document Requirements → Validate Requirements

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Key Message: Another key output of the SE process. Defines the types of requirements.

Figure shows the process used on a project to develop requirements.

Once developed they must be managed, which relates to the cross cutting activity of Configuration Management, which will be discussed later.
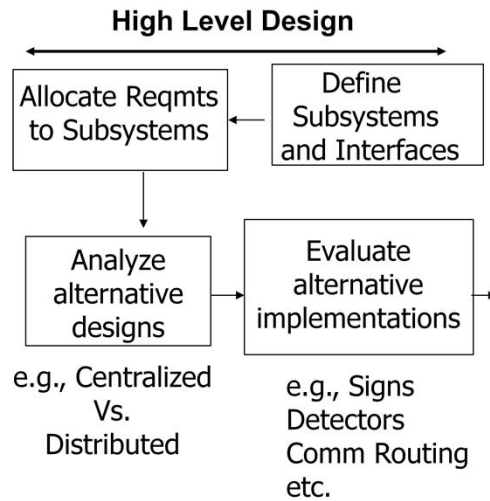
Note that requirements may already exist from similar types of projects within an agency, or in the case of field device deployments, the project may operate off of agency specifications for the devices.

At this step a verification plan is also developed that will describe how the requirements will be verified or tested (as shown on the right side of the "V").

Source: *Systems Engineering for ITS—An Introduction for Transportation Professionals*, USDOT, September 2006, http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf, Fig. 16, p. 34 (hereafter called SEHB)

High Level Design

- Begin definition of problem solution
  - Identify Subsystems and key Interfaces
- Allocate requirements to Subsystems
- Create a project level architecture
- Analyze alternative designs

High Level Design

Allocate Reqmts to Subsystems ← Define Subsystems and Interfaces

Analyze alternative designs → Evaluate alternative implementations →

e.g., Centralized Vs. Distributed

e.g., Signs Detectors Comm Routing etc.

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Key Message: High Level Design

Up until now we have defined the project without defining the design—here is where we start to define the design.

The key outputs of the High Level Design step are to break the system into subsystems and define the key interfaces between the subsystems. One way to do this is to create a project level architecture for the system. This can be an ITS project architecture or it could be a more detailed view of major components (meaning the subsystems or an additional level of decomposition) and communications links. At this step, the identification of ITS standards is made to support the defined inerfaces.

Source: Modification of diagram from National ITS Architecture Team presentation on the "V."

Detailed Design

- Define how the system will be built
- Define components: hardware, software, database elements, firmware, etc.
- Create procurement specifications
- Design any custom hardware or software modules

Detailed Design

Existing Vendor Products? — No → Prototype User Interface

Yes ↓

Select Vendor Products

Develop Detailed HW/SW Specifications

Implementation
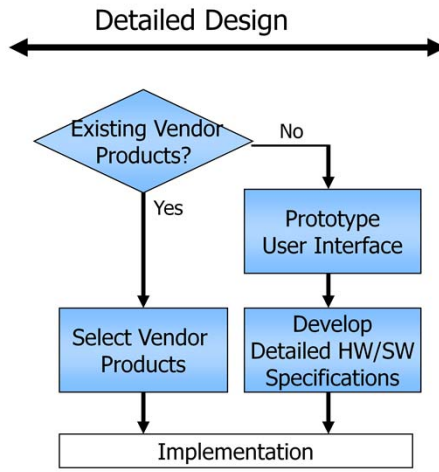
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Key Message: Detailed Design—bullets show some key activities of this step.

Diagram shows a key decision point in step—for each portion of design. Will existing vendor products meet the requirements?

Each subsystem is further defined by components of hardware, software, database elements, firmware, etc. For these components, Detailed Design specialists in the respective fields create documentation (build-to specifications) which will be used to build or procure the individual components. If there is custom hardware or software to be developed, the detailed design of these components or software modules is performed. In practice, most of the hardware used in ITS projects is existing vendor offerings, so little if any hardware design is required. Development of custom software is more common, but even here most ITS projects use vendor software that may be customized for the specific project. This detailed design includes the detailed definition of interfaces, which includes the definition of the communications to be used to link up the various hardware subsystems or components in the project. Included in the interface definition and communications design is the detailed customization of the ITS standards to be used.

Source: SEHB Fig. 21, p. 48.

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Procurement/Development

- This step involves hardware fabrication, software coding, database implementation
- Existing Vendor Products are procured and configured
- Concurrently, unit test procedures are developed to demonstrate how well the detailed design is met
- At the end of this step, the system is ready for testing to begin

Key Message: Describes some key activities of this step.

Procurement is done based on the set of requirements developed, or based on specifications created in detailed design step.

Concurrent with this effort, unit test procedures are developed that will be used to demonstrate how the products will meet the detailed design. At the completion of this stage, the developed products are ready for unit test.

Unit Test

- Hardware and software development are verified against unit verification plan.
- Verify that the delivered components match the documented detailed design.
- For existing vendor hardware/software, perform acceptance testing to show that the hardware and software meet requirements for the unit

Implement
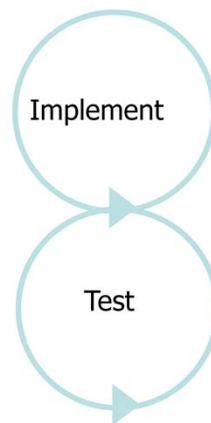
Test

Walkthroughs

Inspections

Reviews

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Key Message: The purpose of unit testing is to verify that the delivered components match the documented Detailed Design. In the case of the procurement of COTS existing vendor hardware or software, this unit testing would take the form of acceptance tests that are performed to show that the hardware and software meet the requirements that have been allocated to each unit.

Source: SEHB, Fig. 26, p. 55.

Subsystem Integration and Verification

- Integrate components and verify at the subsystem level using verification procedures
- Verification occurs iteratively. Verify one subsystem before proceeding to the next.
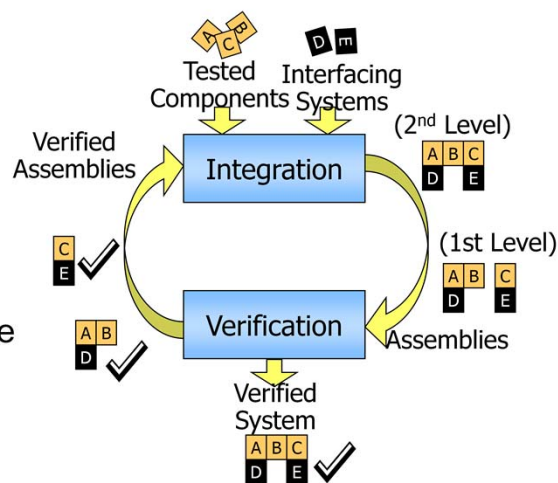
Source: SEHB, fig. 27, p.60

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Key Message: One of the key features of subsystem integration and verification is its iterative nature. Normally a project will integrate a portion of the system, verify it through testing, then integrate more of the system, verify it through testing, and so on, until the complete system is put together. This would be true for complex system development.

Source: SEHB, Fig. 27, p. 60.

System Verification

- Verification confirms that a product meets its requirements
- Verification ensures that the product is built right
- Two parts to verification:
  - Factory Test—performed in a controlled environment
  - On-site Test—performed in the operating environment, after system deployment
- In all cases, verification procedures are followed

Key Message: System verification is often done in two parts. The first part is done under a controlled environment (sometimes called a "factory test"). The second part is done within the environment that the system is intended to operate (sometimes called "on-site testing/verification") after initial system deployment. At this stage, the system is verified in accordance with the Verification Plan developed as part of the system-level requirements performed early in the development.

Important to allow sufficient time in schedule for verification—may mean beginning factory tests earlier.

Initial System Deployment

- System is installed in the operational environment
- Transferred from the development team to the team that owns and operates it
- Includes delivery of support equipment, documentation, operator training, and other necessary products to support operations and maintenance of the system
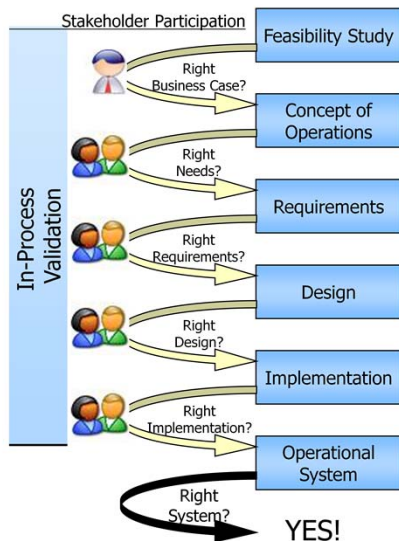- Perform burn-in or acceptance testing to uncover any issues in operational environment

Deliver System | Prepare Facility/Site

Install System

Transition to Operations

Development Team | O&M Team
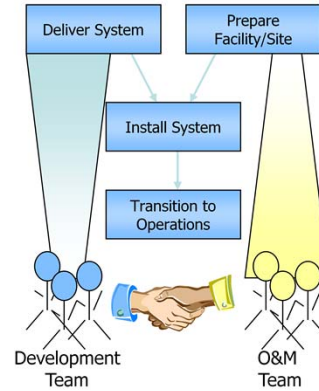
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Key Message: System deployment

Key transition from development to operations

Source: SEHB, Fig. 26, p. 66.

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Key Message:

Two aspects to validation:

1. At each step in process as shown, and
2. Once at end with operational system.

Was the right system built (does it fully address the user's needs) is the question asked at the end.

Source: SEHB, Fig. 30, p. 71.

Operations and Maintenance

- System carries out intended operations
- Routine maintenance is performed
- Staff is trained
- Longest phase: occurs until system is retired or replaced

Key Message: In this phase, the system will carry out the intended operations for which it was designed. During this phase, routine maintenance is performed as well as staff training. This phase is the longest phase, extending through the evolution of the system and ends when the system is retired or replaced.

Changes and Upgrades

- Throughout the operations and maintenance process, changes and upgraded may be needed
- Follow the entire SEP and update original outputs as needed
  - Following the SEP ensures system integrity is maintained
  - SEP may be abbreviated when making changes and upgrades

Key Message: Changes and upgrades can be addressed by going back to the relevant steps of the "V" diagram and updating the outputs as required. Using the "V" process for changes and upgrades will help maintain system integrity (synchronization between the system components and supporting documentation).

A key aspect of the SEP that will be used as part of changes and upgrades in configuration management—a cross-cutting activity that will be discussed in a few slides.

Retirement and Replacement

- Eventually a system will either no longer be needed, or not be cost-effective to operate
- May not be able to maintain
  - e.g., component obsolescence
- Analysis of retirement or replacement may mean implementing a concept exploration step again
  - Then begin the full SE process for replacement

Key Message: In a fitting symmetry to the "V" diagram, this final step is a planning step that can lead back to the beginning of a new project for a system replacement.
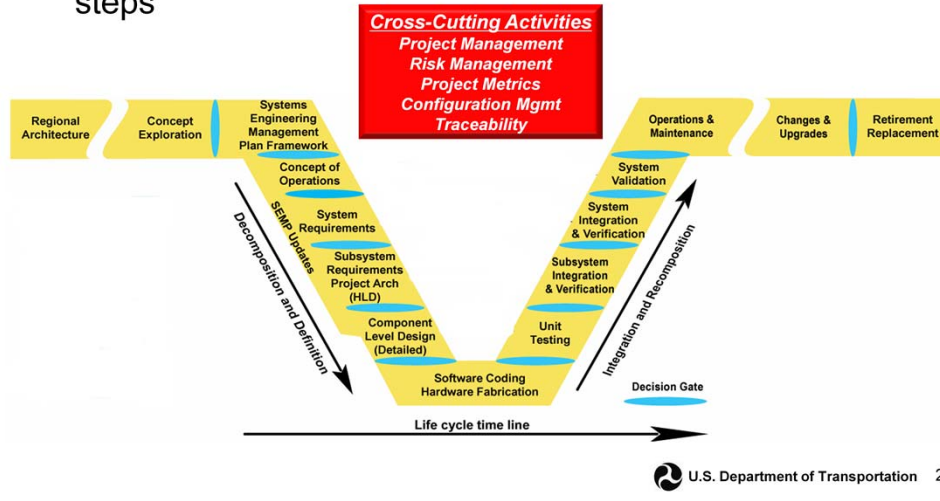
Key Message: Cross-cutting activities begin at the start of the project and can run through into operations.

One slide for each of the activities listed are shown on the following slides.

Source: *SE Guidebook for V-* CCA part of diagram created for this presentation.

Project Management

- Management of cost, schedule, and resources to successfully complete a project
- Closely related to SE; necessary to complete project
- Provides supportive environment to development activities
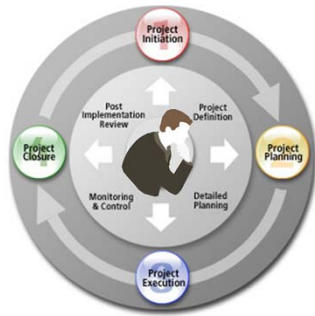
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Key Message: Project management (PM) is a discipline in itself. The diagram on the left shows the key steps of the PM process, while the diagram on the right shows the triangle of constraints that project management seeks to manage.

The system owner or agency has a vested interest in making sure that the development team (usually a contractor team) follows good project management practices, and can require key outputs such as a project management plan and project status reporting as part of the contract deliverables.

Source: National ITS Arch presentation on cross-cutting activities.

Key Message: Identifies key activities of risk management. Diagram shows the flow of risk identification and risk analysis/prioritization
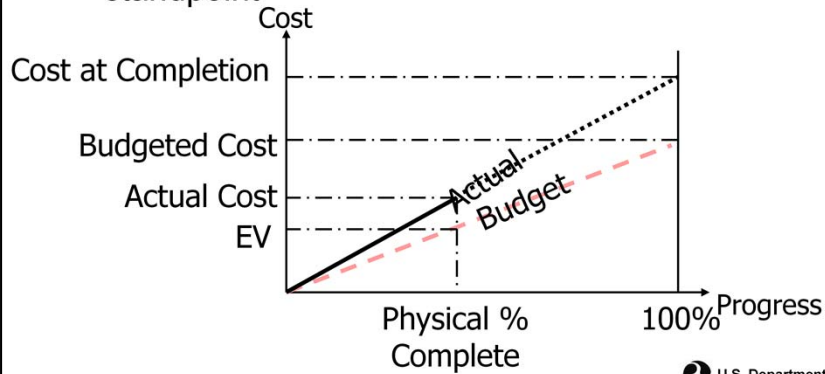
Some items to consider for risk identification include:

o Jurisdiction—does the lead agency have jurisdiction or are there other responsible agencies?

o Software—is there existing and proven software that can be used?

o Interfaces—are new interfaces required or can a project rely on existing interfaces?

o Requirements and procedures—are these well defined and documented?

o Experience—does the staff have the necessary experience to procure, implement, and operate the project?

Source: National ITS Arch presentation on cross-cutting activities.

Key Message: Shows definition and example of project metrics

Project metrics are measures that are used to track and monitor the project and the expected technical performance of the system development effort. The identification and monitoring of metrics allow the team to determine if the project is "on track" both programmatically and technically. Programmatic metrics might be simple budget and schedule status. Technical metrics could involve measuring the number of requirements defined, or the number of requirements changed over a period of time. These metrics are a key part of the project management process.

Configuration Management

- Process to establish and maintain consistency of a product
  - Ensures system integrity is maintained
- Components:
  - Configuration Management Planning
  - Configuration Identification
  - Change Management
  - Status Accounting
- Process documented in SEMP or Project Management Plan

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Key Message: Shows definition and steps in CM process.

Configuration management is defined as: "A management process for establishing and maintaining consistency of a product's performance, functional, and physical attributes with its requirements, design and operational information throughout its life" (*A Guide to the Project Management Body of Knowledge* (PMBOK® Guide), 2013). More than just defining the current state of a system, configuration management involves managing changes that are made to the system throughout its life.

Keeping configuration control of documentation as well as hardware/software allows an agency to reuse some of the SE documents for other related projects.

Traceability

- Ensures that different outputs of the SEP process properly relate to each other
- Centers on relationship of requirements to rest of project
- Traceability must work backwards and forwards
  - Each need in ConOps traces to a system requirement
  - Design specifications trace back to requirements
- Process continues through each stage of SEP.

Key Message: Key aspect of SEP – key way to ensure quality of outputs.

SEP Summary

- Covers entire life cycle of system
- The process should be scaled for each system/project
  - Not one size fits all!
  - Small projects use less resources to address key steps or may combine steps
  - High-risk projects require more robust SEP
  - Define how SEP tailored for each system/project as part of SEMP

Key Message: Scalability of SEP

The SEP summary provides a final chart to emphasize a key aspect of SEP—the scalability

Related Topics

Other topics that are closely related to the Systems Engineering Process

- ITS Architectures
  - National ITS Architecture
  - Regional ITS Architectures
  - ITS Project Architectures
- ITS Standards
- Applying the SE Process to Project Development
- Transportation Planning

Key Message: Lists remaining topics of module

National ITS Architecture

- Provides a common framework for planning, defining, and integrating ITS
- The architecture defines:
  - The functions that are required for ITS
  - The physical entities or subsystems where these functions reside
  - The information flows and data flows that connect these functions and physical subsystems
  - View at http://www.iteris.com/itsarch/index.htm

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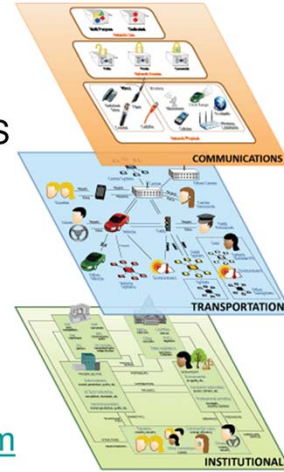
Key Message: National ITS Arch

Framework or template for defining arch.

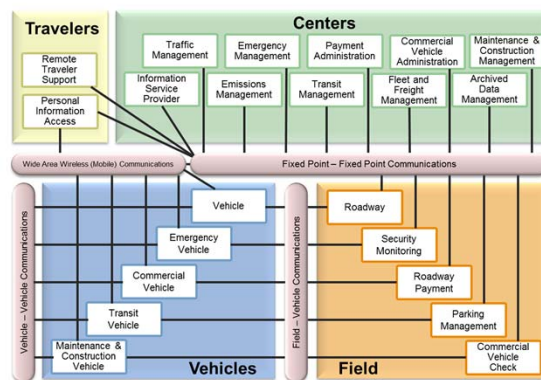Use the template to develop other types of arch mentioned next.

Diagram illustrates that there are three layers to the National ITS Arch

The current National ITS Arch is Version 7.0

Source: National ITS Arch Web site (URL shown above)

Key Message: Shows key depiction of Physical Arch—the "Sausage diagram"

Source: National ITS Arch Web site: http://www.iteris.com/itsarch/index.htm

Regional ITS Architectures

- Regional ITS Architectures define the plans, programs, goals, and objectives for implementation of ITS within a more local scope
  - Regional specific plan for the deployment and integration of ITS
- Regional ITS Architectures use the National ITS Architecture as a template
- 23 CFR 940.9 defines the nine required elements of a regional ITS architecture

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Key Message: Definition of Regional ITS Arch

References the key FHWA Rule/ITS Policy of arch.
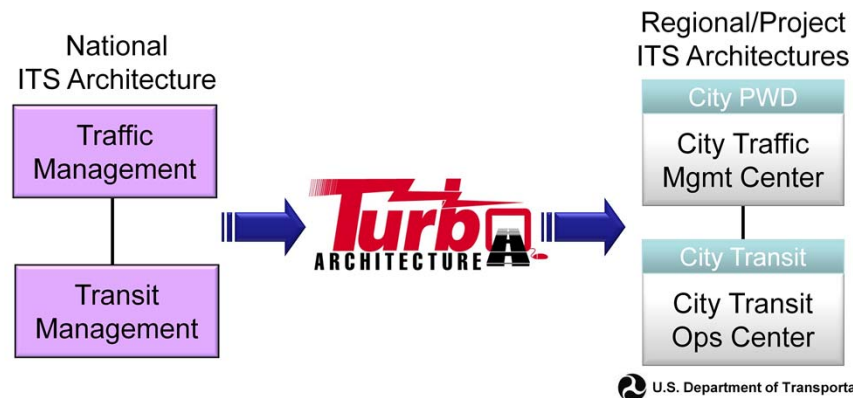
Regional ITS Arch – Rule 23 CFR 940.9

The regional ITS architecture shall include, at a minimum:

(1) A description of the region;

(2) Identification of participating agencies and other stakeholders;

(3) An operational concept that identifies the roles and responsibilities of participating agencies and stakeholders;

(4) Any agreements (existing or new) required for operations,

(5) System functional requirements;

(6) Interface requirements and information exchanges with planned and existing systems and subsystems;

(7) Identification of ITS standards supporting regional and national interoperability; and

(8) The sequence of projects required for implementation.

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Key Message: Lists Requirements of Rule

**Key Message:** Turbo Architecture will help you use the process to develop a regional ITS architecture.

Turbo is a free download from the National ITS Architecture Web site.

Allows you to personalize and customize the National ITS Architecture for a specific region or project. In this example, we take a general interface between a traffic management subsystem and a transit management subsystem and use that as a template to define the interface between a city PWD and city Transit.

Source: National ITS Architecture training presentation.

ITS Project Architectures

- Provide a high level view of a project focusing on the systems, interfaces, and information flows relevant to the project
- Typical output of the High Level Design step
- Essentially a subset of the Regional ITS Architecture, which is relevant to a specific project; can be used to meet requirements of 23 CFR 940.11

Regional ITS Architecture

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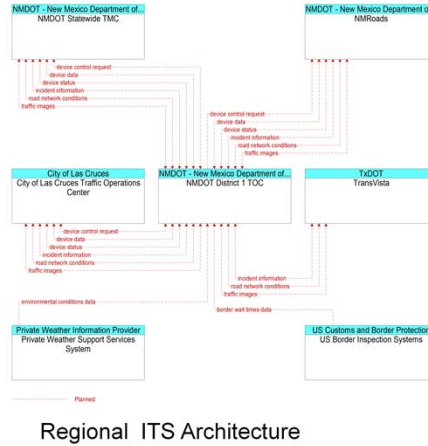
Key Message: Defines the third type of architecture—project architecture—and gives an example of a project arch drawn from Turbo Arch tool

Requirements of 23 CFR 940.11 will be discussed in a couple of charts.

Source: Regional ITS Architecture. Permission provided by Consensus Systems Technologies.

ITS Standards

- ITS Standards define how ITS systems, products, and components can interconnect, exchange information, and interact to deliver services within a transportation network
- Ensure interoperability between products of different manufacturers
- Types of Standards
  - Data transferred on an interface
  - Communications protocols used to send data
  - Hardware specifications
- More about ITS standards can be found at http://www.pcb.its.dot.gov/stds_training.aspx

Key Message: Definition of ITS Standards—reference to place to get training and info on them.
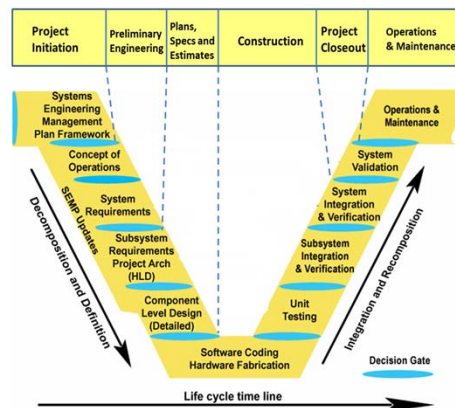
Key Message: Using SEP - relates SEP to traditional transportation development process.

The typical project initiation phase includes activities that occur prior to the start of the project, which includes the procurement process. The impact of SEP on ITS project procurement is described in the document: *Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) Systems*

Source: Bottom "V" from SEGB, top diagram created for this presentation

Systems Engineering Analysis Requirements

- 23 CFR 940.11 defines seven requirements for all projects receiving funding via the Highway Trust Fund.
- Level of detail of the analysis should be commensurate to scope of the project.
  - Higher risk projects require a more detailed analysis.
- The federal requirements are closely aligned to the SEP.

Key Message: Highlights SE analysis requirements of 23 CFR 940.

23 CFR 940.11 Requirements

The systems engineering analysis shall include, at a minimum:

1) Identification of portions of the regional ITS architecture being implemented;
2) Identification of participating agencies roles and responsibilities;
3) Requirements definitions;
4) Analysis of alternative system configurations and technology options to meet requirements;
5) Procurement options;
6) Identification of applicable ITS standards and testing procedures; and
7) Procedures and resources necessary for operations and management of the system.

Key Message: Defines SE analysis requirements of 23 CFR 940.

Relationship to Transportation Planning

- The outer parts of the SEP "V" Diagram fit within the structure of the transportation planning process.
- Long Range Transportation Plan (LRTP) for a state or MPO contains transportation projects that may be undertaken in the medium or long term.
- Transportation Improvement Program (TIP) contains projects that will be undertaken within four years.
- The Concept Exploration Phase of the SEP can provide input to both the TIP and LRTP.

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Key Message: Reference to how SEP fits into transportation planning

Because ITS systems have life cycles that are often less than 10 years, transportation planning needs to include explicit consideration of technology update or replacement; e.g., as system preservation projects in the regional Regional ITS Architecture Guidance Document ITS architecture. A more complete discussion of how the regional ITS architecture supports transportation planning can be found in the and in Applying a Regional ITS Architecture to Support Planning for Operations: A Primer.

Summary

- The Systems Engineering Process (SEP) is an approach that manages the entire life cycle of an ITS System.
- The steps of the SEP can be described using the "V" Model.
- Cross-cutting activities occur throughout the SEP.
- ITS Architectures, ITS Standards, and Transportation Planning are all related to the SEP.
- The SEP is used for ITS Project Development to meet Federal requirements.

References

- *SE Guidebook for ITS*:
  http://www.fhwa.dot.gov/cadiv/segb
- *INCOSE Handbook* (2007)
- US National ITS Architecture:
  http://www.iteris.com/itsarch/index.htm
- ITS PCB Standards Training:
  http://www.pcb.its.dot.gov/stds_training.aspx

List publications/Web site links, etc. for additional information on the module topic.

Questions?

1. What are the key benefits of using a SEP?
2. What are the key contributions of the Concept of Operations and the System Requirements?
3. Describe the difference between verification and validation.
4. Describe the importance of configuration management and traceability.
5. Describe the relationship between a regional ITS architecture and the SEP.

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Answers:

Question 1:

• Improve quality of products created by an ITS project

• Reduce the risk of schedule and cost overruns

• Increase the likelihood that user needs will be met

• Improved stakeholder participation

• Better documentation of the end products and development process

• Reduced operational costs

Question 2:

ConOps defines the system from the perspective of the stakeholder and identifies user needs. System requirements define what the system must do, how well it must do it, and under what conditions.

Question 3:

Verification ensures that a system meets all requirements. Validation ensures that the system meets intended needs. In other words, verification answers "Did I build the system correctly?" and validation answers "Did I build the correct system?"

Question 4:

Configuration Management ensures that all changes are properly documented, to ensure integrity of the system. Traceability ensures proper linkage between each step of the SEP. For example, all user needs are met by requirements, and all requirements meet user needs (forwards and backwards traceability).

Question 5:

The regional ITS architecture is an input to the SEP to provide a high level framework for a project, or

project architecture. A project is subset of the regional ITS architecture.